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Validation of the Rocky Flats Plant Radionuclide Inventory in the Historic Data Task Using SWEPP Assay Data

Volume 2

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Idaho Completion Project

Bechtel BWXT Idaho, LLC

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ABSTRACT

This report presents the results of a descriptive statistical analysis of the isotopic characteristics of radioactive waste stored at the Idaho National Engineering and Environmental Laboratory's Radioactive Waste Management Complex (RWMC). The report makes use of data on current stored waste, as well as previously stored waste, that has been shipped to the Department of Energy's Waste Isolation Pilot Plant for permanent storage.

Analysis results are presented on a waste type basis. Each waste type is comprised of one or more related Item Description Codes. Not all waste types at the RWMC are covered in this report. The analysis was restricted to those waste types of interest because of their similarity to waste currently buried at the Subsurface Disposal Area. The analysis was further restricted to only those waste types for which a completed measurement uncertainty analysis exists as a result of waste characterization activities associated with the recently completed 3100 cubic meters project.

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CONTENTS

FIGURES

TABLES

ACRONYMS

AK	acceptable knowledge
CIDRA	Contaminant Inventory Database for Risk Assessment
EDF	Engineering Design File
HDT	Historic Data Task
IDC	Item Description Code
INEEL	Idaho National Engineering and Environmental Laboratory
PAN	Passive/Active Neutron
RFP	Rocky Flats Plant
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SGRS	SWEPP Gamma-ray Spectrometer
SWEPP	Stored Waste Experimental Pilot Plant
WILD	Waste Information and Location Database
WIPP	Waste Isolation Pilot Plant

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1. INTRODUCTION

In 1995, a report containing a comprehensive account of the radiological content of waste buried in the Subsurface Disposal Area (SDA) located at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering and Environmental Laboratory (INEEL) was completed. The project to produce the report is commonly referred to as the Historic Data Task (HDT). The purpose of the HDT was to support a baseline risk assessment as well as potential environmental remediation activities. Data from the HDT reside in the Contaminant Inventory Database for Risk Assessment (CIDRA).

During the HDT effort, estimates of the SDA inventory were compared for completeness against inventories in previous reports, other databases, and environmental monitoring data at the RWMC. Another source of data with the potential for providing a level of validation for the HDT radionuclide inventory results is the radioassay data for waste originating at the Rocky Flats Plant (RFP) that was stored aboveground at the RWMC. Much of this RFP waste has been assayed at the RWMC's Stored Waste Experimental Pilot Plant (SWEPP) using either the Passive/Active Neutron (PAN) assay system or the SWEPP Gamma-Ray Spectrometer (SGRS) Absolute assay system as required prior to shipment to the Waste Isolation Pilot Plant (WIPP) in New Mexico. Since much of the aboveground RFP waste came from some of the same waste streams as the buried waste, an analysis of the SWEPP data can provide a means of validating the HDT radionuclide inventory for these waste streams.

The purpose of this report is to estimate the radionuclide content of RFP waste buried at the SDA using isotopic concentration data obtained from a recent summary analysis of the radioassay results for drums of the same waste types assayed at the INEEL SWEPP facility. Estimates of plutonium and uranium isotope mass and Curie content are derived for five waste types present in the buried waste. Uncertainty values are also reported. These results are compared to the HDT inventory assessment.

2. DATA

2.1 Waste Types

Not all waste types at the RWMC were considered for this report. The analysis was restricted to those waste types common to both the buried SDA waste and the SWEPP processed waste stored aboveground. The analysis was further restricted to only those waste types for which a detailed measurement uncertainty analysis had been previously completed. For most waste types, the uncertainty analyses indicated the need for substantial bias correction in the reported isotopic mass values; thus, data for waste types for which no bias corrections have been developed were deemed too unreliable for this study.

Five RFP waste streams met the criteria for this analysis. These waste streams are identified by different waste generator (e.g., RFP building number), type designations, and by a waste stream code in the HDT. In the SWEPP data, the primary designator is the item description code (IDC). The correspondence between the waste designations compared in the two data sets is given in Table 2-1.

Table 2-1. Comparision of waste type descriptors and codes.

Waste Description	HDT Waste Type	SWEPP Item Description Codes
First and second stage sludge	741-742 IV	001
	RFO-DOW-3H	002
Organic setup sludge	743 IV	003
	RFO-DOW-15H	
Special setups sludge	744 IV	004
	RFO-DOW-2H	
Graphite	771-776 Graphite	300
	RFO-DOW-11H	301
		303
		310
		312
Filters and insulation	771-776 III	328
	RFO-DOW-6H	335
		490

2.2 Radionuclides

SDA inventory values were calculated for the plutonium isotopes Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242. Isotopes for uranium include U-233, U-234, U-235, and U-238. Am-241 estimates were also calculated. Some data on Np-237 were available in the SWEPP data but not for the HDT. A limited analysis of the neptunium data was performed to assess whether there was any indication of excess neptunium in the waste streams (in excess of the expected quantities due to the decay of Am-241).

2.3 Time Frame

The SWEPP inventory of waste drums consists of waste shipped to the INEEL from 1970–1989. For the comparison of characteristics of this waste to the buried waste (which was all shipped to the INEEL prior to 1970) to be valid, requires the assumption that the waste shipped before and after 1970 was essentially similar in regard to radionuclide content. This study considered only buried waste in the given waste streams that was shipped after January 1, 1964, after the start of the waste drum assay system, the scarfing of graphite molds, the recycling of loaded HEPA filters, and other changes that resulted from a 1964 report on plutonium material unaccounted for at RFP (Zodtner and Rogers 1964).

2.4 SWEPP PAN Data

The relevant SWEPP data for this analysis were obtained from a comprehensive analysis of all available waste drum assays as reported in Volume 1 of this two-volume report. The data cover drums currently stored at the RWMC, as well as previously stored waste that has been shipped to WIPP. Altogether, assay data from approximately 5,000 waste drums were utilized in the analysis.

Because the SWEPP data were obtained with two different assay systems (the PAN and SGRS Absolute systems), some characteristics of the data vary in regards to the method in which isotope specific mass and activity values were obtained. PAN system assays use assumed default weapons grade Pu mass fractions to obtain Pu isotope specific data. That is, the PAN system measures either Pu-238 (in the passive mode) or Pu-239 (in the active mode) directly, and then calculates values for the other Pu isotopes based on the assumed mass fractions. The PAN system also determines U-234 mass by applying a fixed assumed isotopic ratio to the U-235 mass. In contrast, the SGRS Absolute system measures all plutonium and uranium isotopes independently (i.e., without employing assumed fixed isotopic ratios). Both systems provide Am-241 values without relying on assumed mass fractions. For details, see Volume 1.

It should be noted that the SWEPP data do not comprise a random sample of a population of waste drums. Rather, it is a complete collection of data on all waste drums assayed during the time period described (less drums whose assays were excluded for various data quality or related issues). Hence, the SWEPP results may or may not be unbiased estimates of the radionuclide content of the RWMC accessible stored waste population. The SWEPP results are, however, the best waste stream specific estimates possible and are thus appropriate to use in calculating an estimate of the buried waste inventory.

2.5 HDT Data

Isotopic mass data from the HDT study came from a query of the CIDRA database for the waste streams and time frame given earlier. The specific details of the query are given in Table 2-2.

Table 2-2. Radionuclide inventory database query.

Data Source	Query Criteria	Query Returned Data Set Parameters
Contamination Inventory Database for Risk Assessment (CIDRA)	1. First & Second Stage Sludge – WS: RFO-DOW-3H • By Year: >01/01/1964 • Associated Nuclides • Curies per Nuclide 2. Organic Sludge – WS: RFO-DOW-15H • By Year: >01/01/1964 • Nuclide • Curies per Nuclide 3. Special Setups – WS: RFO-DOW-2H • By Year: >01/01/1964 • Associated Nuclides • Curies per Nuclide 4. Graphite – WS: RFO-DOW-11H • By Year: >01/01/1964 • Associated Nuclides • Curies per Nuclide 5. Filters – WS: RFO-DOW-6H • By Year: >01/01/1964 • Associated Nuclides • Curies per Nuclide	• Waste Stream • Year of Disposal • Nuclide • Waste Stream Curie Total by Nuclide per year • Waste Stream Curie Total by Nuclide

2.6 Shipment Data

Shipment data came from a query of the Waste Information and Location Database (WILD) for the desired waste types and timeframe. The specific parameters are listed in Table 2-3.

Table 2-3. Shipping record database query.

Data Source	Query Criteria	Query Returned Data Set Parameters
Waste Information and Location Database (WILD)	1. First & Second Stage Sludge – WS: RFO-DOW-3H • Waste Type Code: IV • Generator: RFO741, RFO742 • Shipment Date: >01/01/1964 2. Organic Sludge – WS: RFO-DOW-15H • Waste Type Code: IV • Generator: RFO743 • Shipment Date: >01/01/1964 3. Special Setups – WS: RFO-DOW-2H • Waste Type Code: IV • Generator: RFO744 • Shipment Date: >01/01/1964 4. Graphite – WS: RFO-DOW-11H • Waste Type Code: GRAPHITE • Generator: RFO771, RFO776 • Shipment Date: >01/01/1964 5. Filters – WS: RFO-DOW-6H • Waste Type Code: III • Generator: RFO771, RFO776 • Shipment Date: >01/01/1964	• Shipment ID • Description of shipment contents • Shipment generator • Rocky Flats Waste Type designation • Shipment container count and container types • Shipment weight (LBS) • Shipment volume (FT3) • SDA disposal location

Note: the WILD database is a production database, but is currently undergoing a data validation and verification effort. The data retrieved based on the above query criteria is subject to change based on results of data validation and verification.

2.7 Data Quality Issues

Some inconsistencies in results from the WILD database were found. These issues were investigated and corrections made in both the data used for this analysis and in the WILD database itself. The data analyzed reflect the current database contents as of approximately March 15, 2004.

2.8 Decay Dates

The short half-lives of Pu-238 and Pu-241 make decay an important factor in the comparison of inventory quantities based on the SWEPP data vs. the CIDRA data.

The CIDRA database reports plutonium isotopes based on assumed as-generated weapons grade plutonium mass fractions. These mass fractions are listed in the HDT report and repeated here for convenience in Table 2-4 (LMITCO 1995).

Table 2-4. Assumed weapons grade plutonium mass fractions.

Isotope	Mass fraction
Pu-238	.0001
Pu-239	.9389
Pu-240	.0575
Pu-241	.0034
Pu-242	.0002

The two SWEPP assay systems also report plutonium isotopic data using assumed plutonium mass fractions, but based on a study in Engineering Design File-1609 (EDF-1609), in which actual measured mass fractions were corrected to a decay date of 6/1/2000. To make the SWEPP data comparable to the CIDRA data in terms of assumed plutonium mass fractions, the CIDRA assumed mass fractions were applied to the SWEPP reported Pu-239 mass to obtain mass values for the other plutonium isotopes. CIDRA and SWEPP both assumed Pu-239 mass fractions to within 0.05%, and the half-life of Pu-239 is long enough that there has been less than 1% decay over the lifetime of the waste. So, regardless of when it was actually assayed, the Pu-239 mass provides a good basis for calculating as-generated weapons grade plutonium isotopic content for the other plutonium isotopes.

The half-lives of the uranium isotopes are long enough that any differences in the CIDRA and SWEPP measures due to decay are minimal. Hence, no decay corrections were made to the uranium data during the analysis.

A difference in Am-241 values of as much as 6% (assuming a 40-year decay) might exist in the SWEPP data compared to the CIDRA data. A cursory comparison of the SWEPP measured plutonium isotopic ratios to weapons grade plutonium values indicated an average age of approximately 15 years. This age would correspond to a decay of less than 3% for Am-241. Because of this small value and the amount of effort it would take to determine the actual age of drums assayed at SWEPP and then decay correcting the measured Am-241 contents, no corrections for decay in Am-241 quantities were made for this analysis.

3. CALCULATION METHODS

Calculation of the buried waste radionuclide inventory was achieved by using WILD data to estimate the mass of waste material for each of the waste streams analyzed, and then applying isotope specific concentration values estimated in the SWEPP data analysis. In the remainder of this document, these results will be referred to as the SWEPP/WILD inventory estimates (as opposed to the HDT estimates of the buried waste inventory obtained from the CIDRA database). The major steps in the calculations were as follows:

- Obtain data on number of containers, container types, and gross weight of waste for each RFP waste type from WILD on a shipment by shipment basis.

- Based on assumed container weights (see details below), calculate the net weight of the waste for each shipment in kg.

- For plutonium isotopes, apply the Pu-239 concentration (grams of Pu-239 per kg waste) from the SWEPP waste study to the WILD net weight for the buried waste to get the new estimate of Pu-239 mass and curie content of Pu-239 in the buried waste. Apply the CIDRA assumed plutonium mass fractions to the Pu-239 quantities to get SWEPP estimates of the other plutonium isotopes.

- For each of the uranium isotopes and Am-241, apply the estimated isotope-specific concentration from the SWEPP data to the WILD net weight to get the SWEPP estimates of the buried inventory.

- Obtain uncertainty estimates for concentration values from the SWEPP study, weapons grade plutonium mass fraction uncertainty estimates derived from the acceptable knowledge (AK) information, and net weight uncertainties based on expert judgment. Use these values and standard propagation of error methods to obtain uncertainty values for the SWEPP estimates of the buried waste inventory. (Note, all uncertainties are reported as "one-sigma" values in this report.)

3.1 Container Weights

In calculating net weights of waste shipments, 30-gal drums were assumed to weigh 42 lb and 55-gal drums 50 lb. These estimates were taken from EDF-837. The drums were assumed to be absent rigid liners, as their use did not begin until 1972 (Clements 1982).

Based on the shipment descriptions, most wooden boxes appeared to be 4 x 4 x 7 ft. standard wood boxes. These were assumed to be box type BXW code E weighing 620 lbs as described in EDF-837. Based on gross weight and stated wasted volume, wooden boxes in the records for 14 shipments appeared to be a smaller box type and weight than the BXW code E boxes. Box weights for these shipments were set at 200 lbs for the net weight calculations.

Some waste was shipped in cardboard boxes, and some drums or wood boxes contained waste in cardboard boxes. The weight of any cardboard containers was assumed to be negligible in the net weight calculations.

3.2 Uncertainty Estimates

Uncertainty values for the SWEPP data on radioisotope concentration are given in Volume 1. These uncertainty values were combined with those for the buried waste net weights to obtain the uncertainties in the estimated inventory. Also needed in the calculation of plutonium isotope inventory values are uncertainty values for the weapons grade plutonium mass fractions.

3.2.1 Plutonium Mass Fraction Uncertainty

Weapons grade plutonium isotopic mass fraction uncertainties are based on the range given in the INEEL's AK document for RFP waste (LMITCO 1996). The listed range was assumed to be an approximate nominal 95% confidence bound on the true value. Hence, dividing the range by four approximates the standard deviation. The values resulting from this calculation are given in Table 3-1.

Table 3-1. Plutonium isotope mass fraction uncertainties.

Isotope	Stated range in AK document	Derived standard deviation
Pu-238	0.0001-.0005	.0001
Pu-239	.928-.944	.004
Pu-240	.0485-.065	.004
Pu-241	.003-.010	.002
Pu-242	.00005-.0060	.0015

3.2.2 Net Weight Uncertainty

There are two primary sources of uncertainty in the net weight calculations for the buried waste, uncertainty inherent in the scales used to weigh the filled waste containers, and uncertainty in the assumed container weights that are subtracted from the gross weights to yield the net weights.

Scale uncertainty is not likely to be a significant component of the uncertainty in the waste stream net weight calculations. Random errors in individual scale measurements will tend to cancel each other out when individual weights are summed to obtain the total weight for a waste type. For example, a drum scale with as much as 30% random error for each individual measurement will produce a random error in the sum of weights for 1,000 drums of less than 1%. Since most scales should have random errors considerably less than 30% and the number of containers in each of the waste stream categories being considered exceeds 1,000 (in some cases by a considerable amount), random error in the gross weights can be considered as negligible.

Scales may also have a bias error component in their measurements. In properly calibrated scales, this error likely does not exceed a few percentage points on each measurement. Also, bias errors will change randomly over time as scales are recalibrated. In this regard they will tend to cancel each other out in a similar manner to the random errors of measurement. Similarly, bias errors across different scales that might be used will also tend to average out over time. Hence bias errors in the gross weights can also be considered to be negligible.

For each type of container, a constant value is subtracted from the gross weight to get the net weight. Because a constant value is being subtracted from every container of the same type, the error associated with the subtracted value is a bias error that will not be reduced when individual container weights are summed. In the assignment of uncertainty for the container weights it was assumed that the stated container weights deviate from the true weight by no more than 5 lb for drums and 50 lb for boxes. For example, the stated weight of 50 lb for a 55-gal drum is assumed to represent a true weight of between 45 and 55 lb. If this range is treated as a nominal 95% confidence interval for the true weight, then the standard deviation is obtained by dividing the range by four. The bias uncertainties derived for each container type using this method are given in Table 3-2.

Table 3-2. Derived uncertainty values for container weights.

Container type	Assumed weight (lb)	Uncertainty range (lb)	Derived standard deviation (lb)
30-gal	42	37-47	2.5
55-gal	50	45-55	2.5
Small box	200	150-250	25
Large box	620	570-670	25

3.2.3 Possible Sources of Uncertainty Not Included in the Analysis

One source of uncertainty not accounted for in this analysis is uncertainty due to lack of equivalence of the SDA buried waste to SWEPP waste. This is of the most concern for the filters waste as there are notable differences between the description of the contents for the buried waste (e.g. filter sizes), and that for the filters IDC descriptions for the SWEPP waste. However, there is also a potential general loss of comparability due to the difference in time periods in which the SDA vs. the SWEPP waste were generated. Any changes in the processes generating the waste over time have the potential for affecting the radionuclide inventory of a particular waste type.

Database errors (transcription errors, errors in assigning contents, weights, etc., to a shipment) are another potential source of uncertainty not accounted for in this analysis. The WILD database has not been finalized. A number of errors affecting the calculated waste volume were found in the records in the current study. The errors that were found resulted from calculated container volumes, net weights, etc., that were out of the range of possibility or likely values. Errors of this magnitude were easily detectable. Similar errors, but with results not exceeding likely values, may also exist in the data, but have gone undetected.

4. RESULTS

4.1 SWEPP Data

Detailed tables of the SWEPP isotopic concentration value results for each of the five waste types are included in the Appendices to Volume 1. For convenience, the basic data used in the buried waste inventory calculations are repeated in Table 4-1 through Table 4-5. Note that the only plutonium isotope listed is Pu-239 because, as mentioned in the methods section, the other isotopic results for plutonium are obtained by applying weapons grade plutonium mass fractions to the Pu-239 results.

Although some U-233 results were reported in Volume 1, the total over all waste types was a number that was significantly less than zero. Although some negative results are expected for individual drums (due to background subtraction), for the total over all measurements to be less than zero is a strong indication of either no true U-233 present, or poor measurements. Hence, the U-233 results were eliminated from the analysis in this section.

Table 4-1. Isotopic concentrations in SWEPP waste, first and second stage sludge (741-742 IV).

Isotope	SWEPP concentration (g isotope)/(kg waste)	Uncertainty
Pu-239	3.44E-02	4.77E-03
U-233	--	--
U-234	9.97E-05	1.14E-05
U-235	5.06E-02	5.42E-03
U-238	1.61E+01	1.47E+00
Am-241	1.06E-02	7.90E-04

Table 4-2. Isotopic concentrations in SWEPP waste, organic setups sludge (743 IV).

Isotope	SWEPP concentration (g isotope)/(kg waste)	Uncertainty
Pu-239	9.78E-03	1.60E-03
U-233	--	--
U-234	6.58E-07	2.48E-07
U-235	4.14E-04	1.36E-04
U-238	6.41E-02	3.52E-02
Am-241	3.57E-05	1.05E-05

Table 4-3. Isotopic concentrations in SWEPP waste, special setups sludge (744 IV).

Isotope	SWEPP concentration (g isotope)/(kg waste)	Uncertainty
Pu-239	3.28E-01	4.27E-02
U-233	--	--
U-234	1.66E-05	4.82E-06
U-235	1.55E-02	5.26E-03
U-238	--	--
Am-241	1.00E-03	1.19E-04

Table 4-4. Isotopic concentrations in SWEPP waste, graphite (771-776).

Isotope	SWEPP concentration (g isotope)/(kg waste)	Uncertainty
Pu-239	3.67E-01	1.20E-02
U-233	--	--
U-234	4.64E-07	2.68E-07
U-235	4.34E-04	1.25E-04
U-238	--	--
Am-241	9.02E-04	3.18E-05

Table 4-5. Isotopic concentrations in SWEPP waste, filters (771-776 III).

Isotope	SWEPP concentration (g isotope)/(kg waste)	Uncertainty
Pu-239	1.06E+00	1.31E-01
U-233	--	--
U-234	1.43E-06	6.45E-07
U-235	7.11E-04	3.10E-04
U-238	1.17E-01	6.11E-02
Am-241	9.85E-03	2.14E-03

4.2 Buried Waste Inventory Data

The calculated buried waste total net weight for each waste type as determined from the WILD database of shipping records are given in Table 4-6. Uncertainties for the net weights are also given. A summary of the number of WILD database records used in the net weight assessment, and the number and types of containers contained in those records, is given in Table 4-7.

Table 4-6. Buried waste RFP total net weight by waste type.

Waste Type	Mass (kg)	Uncertainty (kg)
First and second stage sludge (741-742 IV)	2.54E+06	1.58E+04
Organic setups sludge (743 IV)	1.95E+06	1.03E+04
Special setups sludge (744 IV)	2.05E+05	1.32E+03
Graphite (771-776)	1.11E+05	2.21E+03
Filters (771-776 III)	2.20E+05	9.44E+02

Table 4-7. Number of WILD database shipment records analyzed and number of containers by types included in those records.

		Number of containers by type			
Waste Type	Number of WILD records	55 gallon drum	30 gallon drum	Wooden box	Cardboard box
First and second stage sludge (741-742 IV)	813	11796	1132	--	--
Organic setups sludge (743 IV)	301	8460	--	--	--
Special setups sludge (744 IV)	235	1082	--	--	--
Graphite (771-776)	130	112	17	1	--
Filters (771-776 III)	99	3	--	77	19

4.3 Estimated Buried Waste Mass and Curie Inventory Using the SWEPP and WILD Data

4.3.1 Results by Waste Type

Using the SWEPP and WILD data from the previous two sections, the SDA RFP buried waste inventory for plutonium, uranium, and americium isotopes were calculated for each waste type by multiplying the net waste weights by the isotopic mass concentration values. The results obtained, along with propagated uncertainties, are given in Table 4-8 through Table 4-13.

Table 4-8. Estimated SDA RFP buried waste isotopic inventory using SWEPP/WILD data, first and second stage sludge (741-742 IV).

Isotope	Mass (g)	Mass uncertainty	Curies	Curies uncertainty
Pu-238	9.31E+00	9.40E+00	1.61E+02	1.63E+02
Pu-239	8.74E+04	1.21E+04	5.50E+03	7.63E+02
Pu-240	5.35E+03	8.32E+02	1.23E+03	1.91E+02
Pu-241	3.17E+02	1.91E+02	3.29E+04	1.99E+04
Pu-242	1.86E+01	1.40E+02	7.39E-02	5.55E-01
U-234	2.53E+02	2.90E+01	1.60E+00	1.83E-01
U-235	1.29E+05	1.38E+04	2.81E-01	3.02E-02
U-238	4.09E+07	3.74E+06	1.39E+01	1.27E+00
Am-241	2.69E+04	2.01E+03	9.35E+04	6.99E+03

Table 4-9. Estimated SDA RFP buried waste isotopic inventory using SWEPP/WILD data, organic setups sludge (743 IV).

Isotope	Mass (g)	Mass uncertainty	Curies	Curies uncertainty
Pu-238	2.04E+00	2.06E+00	3.52E+01	3.57E+01
Pu-239	1.91E+04	3.13E+03	1.20E+03	1.97E+02
Pu-240	1.17E+03	2.08E+02	2.69E+02	4.79E+01
Pu-241	6.92E+01	4.22E+01	7.20E+03	4.39E+03
Pu-242	4.07E+00	3.05E+01	1.62E-02	1.21E-01
U-234	1.29E+00	4.85E-01	8.12E-03	3.06E-03
U-235	8.09E+02	2.66E+02	1.77E-03	5.81E-04
U-238	1.25E+05	6.88E+04	4.26E-02	2.34E-02
Am-241	6.97E+01	2.05E+01	2.42E+02	7.12E+01

Table 4-10. Estimated SDA RFP buried waste isotopic inventory using SWEPP/WILD data, special setups sludge (744 IV).

Isotope	Mass (g)	Mass uncertainty	Curies	Curies uncertainty
Pu-238	7.18E+00	7.24E+00	1.24E+02	1.25E+02
Pu-239	6.74E+04	8.78E+03	4.24E+03	5.52E+02
Pu-240	4.13E+03	6.10E+02	9.49E+02	1.40E+02
Pu-241	2.44E+02	1.47E+02	2.54E+04	1.53E+04
Pu-242	1.44E+01	1.08E+02	5.70E-02	4.27E-01
U-234	3.41E+00	9.90E-01	2.15E-02	6.26E-03
U-235	3.18E+03	1.08E+03	6.96E-03	2.36E-03
U-238	--	--	--	--
Am-241	2.05E+02	2.45E+01	7.13E+02	8.50E+01

Table 4-11. Estimated SDA RFP buried waste isotopic inventory using SWEPP/WILD data, graphite (771-776).

Isotope	Mass (g)	Mass uncertainty	Curies	Curies uncertainty
Pu-238	4.33E+00	4.33E+00	7.48E+01	7.49E+01
Pu-239	4.06E+04	1.56E+03	2.56E+03	9.79E+01
Pu-240	2.49E+03	1.98E+02	5.72E+02	4.55E+01
Pu-241	1.47E+02	8.67E+01	1.53E+04	9.02E+03
Pu-242	8.65E+00	6.49E+01	3.44E-02	2.58E-01
U-234	5.14E-02	2.97E-02	3.25E-04	1.88E-04
U-235	4.80E+01	1.39E+01	1.05E-04	3.03E-05
U-238	--	--	--	--
Am-241	9.98E+01	4.05E+00	3.47E+02	1.40E+01

Table 4-12. Estimated SDA RFP buried waste isotopic inventory using SWEPP/WILD data, filters (771-776 III).

Isotope	Mass (g)	Mass uncertainty	Curies	Curies uncertainty
Pu-238	2.48E+01	2.50E+01	4.92E+02	4.32E+02
Pu-239	2.33E+05	2.88E+04	1.46E+04	1.81E+03
Pu-240	1.43E+04	2.02E+03	3.28E+03	4.65E+02
Pu-241	8.43E+02	5.07E+02	8.77E+04	5.27E+04
Pu-242	4.96E+01	3.72E+02	1.97E-01	1.48E+00
U-233	--	--	--	--
U-234	3.14E-01	1.42E-01	1.98E-03	8.95E-04
U-235	1.56E+02	6.81E+01	3.41E-04	1.49E-04
U-238	2.57E+04	1.34E+04	8.74E-03	4.56E-03
Am-241	2.16E+03	4.70E+02	7.51E+03	1.63E+03

4.3.2 Combined Results

Combining the isotopic data across the tables in the previous two sections gives the estimated total buried waste inventory for the five waste types analyzed. These results are given in Table 4-13.

Table 4-13. Estimated SDA RFP buried waste isotopic inventory using SWEPP/WILD data, combined waste types.

Isotope	Mass (g)	Mass uncertainty	Curies	Curies uncertainty
Pu-238	4.76E+01	2.81E+01	8.24E+02	4.86E+02
Pu-239	4.47E+05	3.26E+04	2.81E+04	2.05E+03
Pu-240	2.74E+04	2.29E+03	6.30E+03	5.27E+02
Pu-241	1.62E+03	5.69E+02	1.68E+05	5.92E+04
Pu-242	9.53E+01	4.18E+02	3.78E-01	1.66E+00
U-234	2.58E+02	2.90E+01	1.63E+00	1.84E-01
U-235	1.33E+05	1.38E+04	2.90E-01	3.03E-02
U-238	4.11E+07	3.75E+06	1.40E+01	1.27E+00
Am-241	2.95E+04	2.07E+03	1.02E+05	7.18E+03
Total	4.17E+07	3.75E+06	3.06E+05	5.97E+04

Another summary view, which will be useful in comparing the inventory based on the SWEPP calculations to that from the HDT, is provided in Table 4-14, which shows total curie content (summed across isotopes) by waste type.

Table 4-14. Estimated SDA RFP buried waste total Curie content using SWEPP/WILD data, by waste type.

Waste Type	Total Curies (all isotopes)	Uncertainty
First and second stage sludge (741-742 IV)	1.33E+05	2.11E+04
Organic setups sludge (743 IV)	8.94E+03	4.40E+03
Special setups sludge (744 IV)	3.14E+04	1.53E+04
Graphite (771-776)	1.88E+04	9.02E+03
Filters (771-776 III)	1.14E+05	5.28E+04
Total	3.06E+05	5.97E+04

4.4 Comparison to HDT Inventory Using CIDRA Data

4.4.1 CIDRA Data

The HDT estimated SDA buried waste inventory for the five waste streams of interest were obtained by querying the CIDRA database as described earlier. Reported uncertainties were propagated using standard error propagation methods. Table 4-15 give the resulting Curie content and propagated error by isotope and by waste type. Note that the CIDRA database did not contain any information on uranium isotopes for the RFP waste. The errors propagated for Table 4-15, were those provided with the CIDRA data. The CIDRA reported uncertainty values for certain isotopes were the same across some waste types. Because of this and other methodological differences between uncertainty estimation in the CIDRA data and the SWEPP/WILD data, comparison of uncertainty bounds across the two data sets should not be taken to indicate true relative differences in uncertainties. However, they are included in the table (and the graphs in the following section) because they are the best estimates available.

Table 4-15. Estimated SDA RFP buried waste Curie content using CIDRA data.

Waste Type	Isotope	Curies	Uncertainty
First and second stage sludge			
(741-742 IV)	Pu-238	1.50E+02	4.73E+01
	Pu-239	5.14E+03	1.61E+03
	Pu-240	1.15E+03	3.61E+02
	Pu-241	3.08E+04	9.65E+03
	Pu-242	6.91E-02	2.16E-02
	Am-241	6.58E+04	6.19E+03
	Total	1.03E+05	1.16E+04
Organic setups sludge			
(743 IV)	Pu-238	4.63E+00	3.92E+01
	Pu-239	1.58E+02	1.34E+03
	Pu-240	3.54E+01	3.00E+02
	Pu-241	9.45E+02	8.01E+03
	Pu-242	2.12E-03	1.79E-02
	Am-241	--	--
	Total	1.14E+03	8.13E+03
Special setups sludge			
(744 IV)	Pu-238	5.35E+00	4.73E+01
	Pu-239	1.83E+02	1.61E+03

	Pu-240	4.09E+01	3.61E+02
	Pu-241	1.09E+03	9.65E+03
	Pu-242	2.45E-03	2.16E-02
	Am-241	--	--
	Total	1.32E+03	9.79E+03
Graphite			
(771-776)	Pu-238	5.39E+01	4.73E+01
	Pu-239	1.84E+03	1.61E+03
	Pu-240	4.13E+02	3.61E+02
	Pu-241	1.10E+04	9.65E+03
	Pu-242	2.48E-02	2.16E-02
	Am-241	--	--
	Total	1.33E+04	9.79E+03
Filters			
(771-776 III)	Pu-238	1.27E+02	4.73E+01
	Pu-239	4.32E+03	1.61E+03
	Pu-240	9.67E+02	3.61E+02
	Pu-241	2.59E+04	9.65E+03
	Pu-242	5.80E-02	2.16E-02
	Am-241	6.76E+02	6.19E+03
	Total	3.20E+04	1.16E+04
Total	Pu-238	3.41E+02	1.02E+02
	Pu-239	1.16E+04	3.49E+03
	Pu-240	2.61E+03	7.82E+02
	Pu-241	6.97E+04	2.09E+04
	Pu-242	1.57E-01	4.67E-02
	Am-241	6.65E+04	8.75E+03
	Total	1.51E+05	2.29E+04

4.4.2 Graphical Comparisons

The SWEPP/WILD inventory estimates are compared to the CIDRA estimates in Figure 4-1 by isotope and Figure 4-2 by waste type. Figure 4-3 through Figure 4-7 show detailed results by isotope for each waste type. In all plots, estimated nominal 95% confidence bounds are plotted (± 2 times the uncertainty values given in the tables from which the data were drawn). For general discussion purposes, when the confidence bounds for two estimates do not overlap, the difference can be considered statistically significant. Conversely, if they do overlap, the difference can be said to be not statistically significant. (Other more formal tests of significance may be more appropriate for some applications of these results.) However, as mentioned in the previous section, caution should be taken in interpreting the results in regard to the size of the error bounds on the data because of differences in methodology used to estimate uncertainty in the CIDRA and SWEPP/WILD data. Because of these methodological differences, conclusions of significant differences based on the plotted error bounds should be interpreted as rough indicators of the true level of significance.

Because the isotopic Curie content values span several orders of magnitude, the results in Figure 4-1 and Figure 4-3 through Figure 4-7 are plotted on a logarithmic scale. (This results in the confidence bounds appearing longer on the low side of the estimated value compared to the high side.)

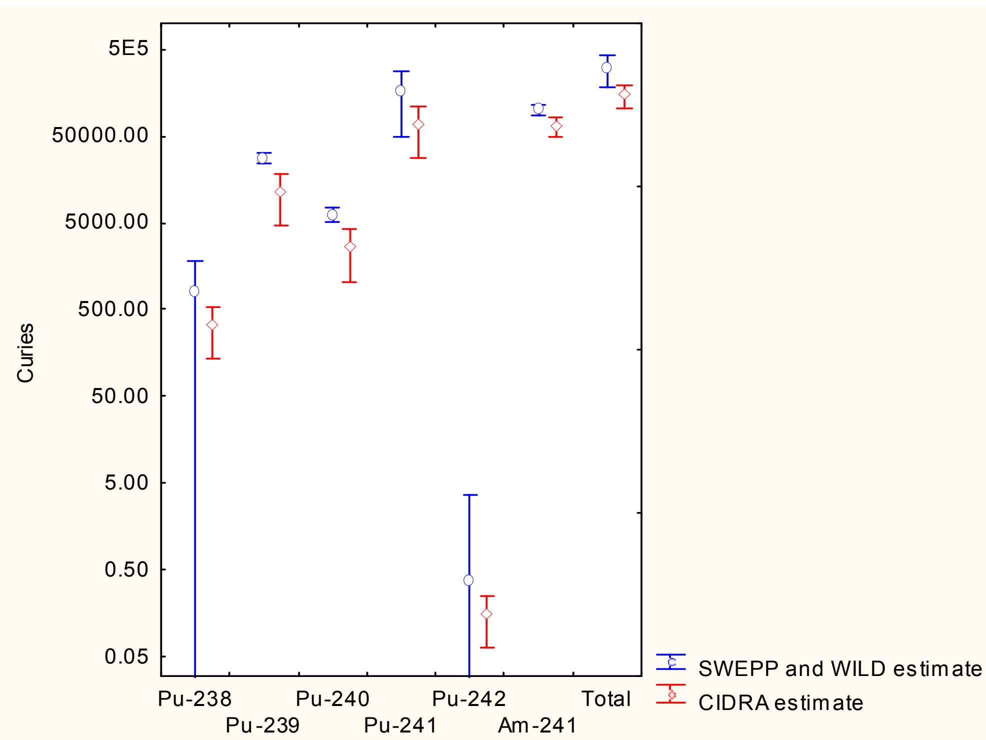

Figure 4-1. SWEPP/WILD vs. CIDRA estimates of SDA RFP buried waste isotopic inventory.

In Figure 4-1, the total Curie content for the SWEPP/WILD data refers to the total including uranium isotopes, while uranium information was not included in the CIDRA data total. However, the comparison is still valid because, to the three significant figures reported in the SWEPP/WILD data totals, the uranium contribution was insignificant. The plot shows that the uncertainty bounds for the total content values of the SWEEP/WILD and CIDRA estimates overlap slightly. However, the results for the individual isotopes indicate that the CIDRA value is always less than the SWEPP/WILD values, and the difference is significant for Pu-239, Pu-240, and Am-241. Because of the large uncertainty bounds for these data, the SWEPP/WILD and CIDRA estimates can be quite divergent, even when the differences are not statistically significant. For example, the estimated Pu-241 content based on the SWEPP/WILD data is 2.4 times that from the CIDRA data, and the SWEPP/WILD total Curie content is 2.0 times that from the CIDRA data.

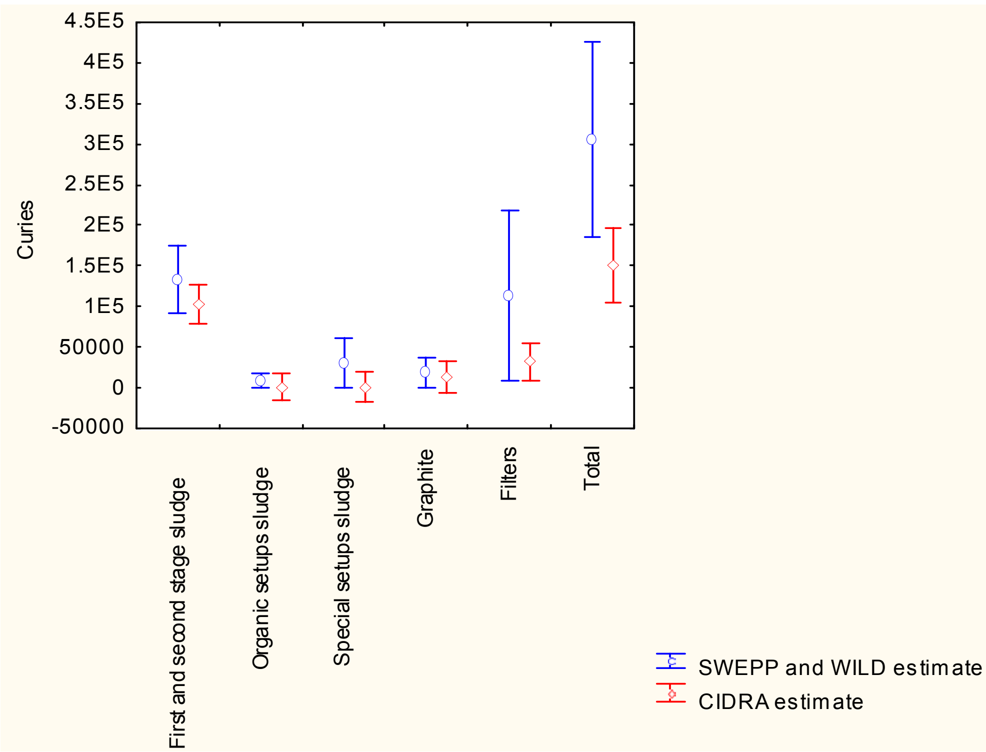

Figure 4-2. SWEPP/WILD vs. CIDRA estimates of SDA RFP total Curie content by waste type.

Figure 4-2 shows that there is a closer agreement between the two sets of estimates when the Curie content by waste type is considered. None of the differences are statistically significant when determined by overlapping confidence bounds.

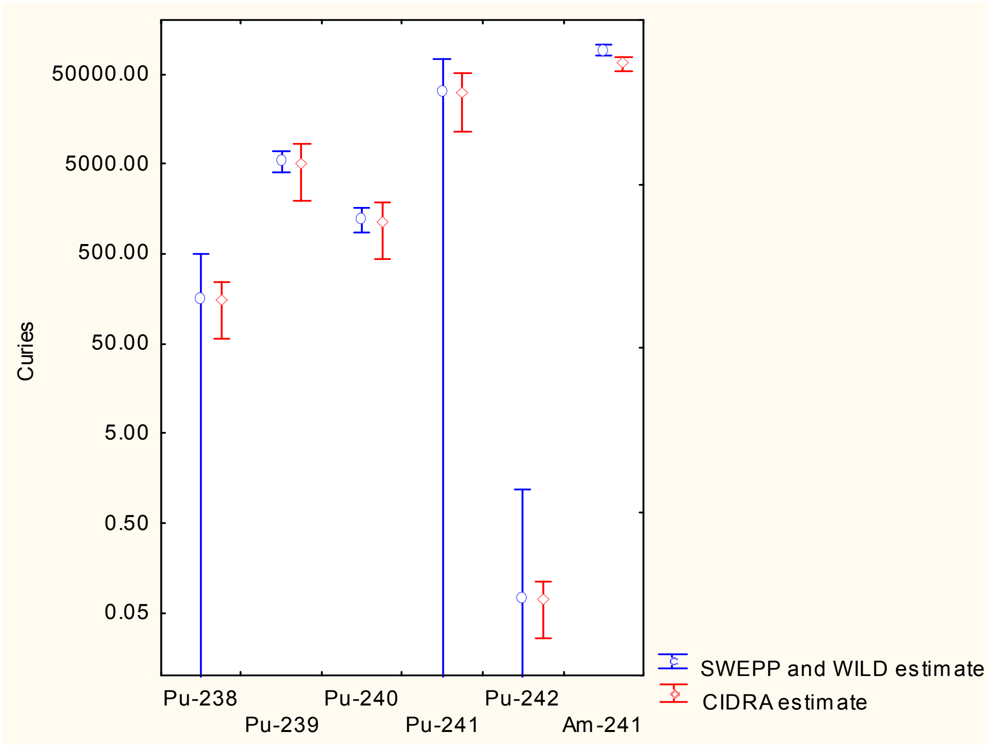

Figure 4-3. SWEPP/WILD vs. CIDRA estimates of SDA RFP buried waste isotopic inventory for first and second stage sludge.

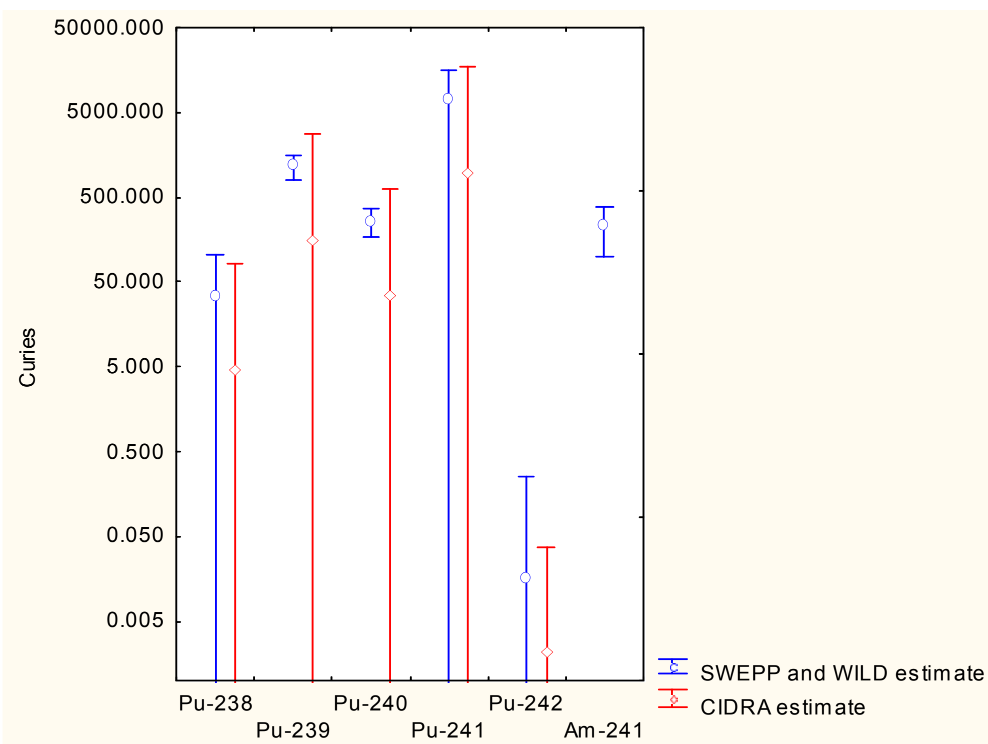

Figure 4-4. SWEPP/WILD vs. CIDRA estimates of SDA RFP buried waste isotopic inventory for organic setups sludge.

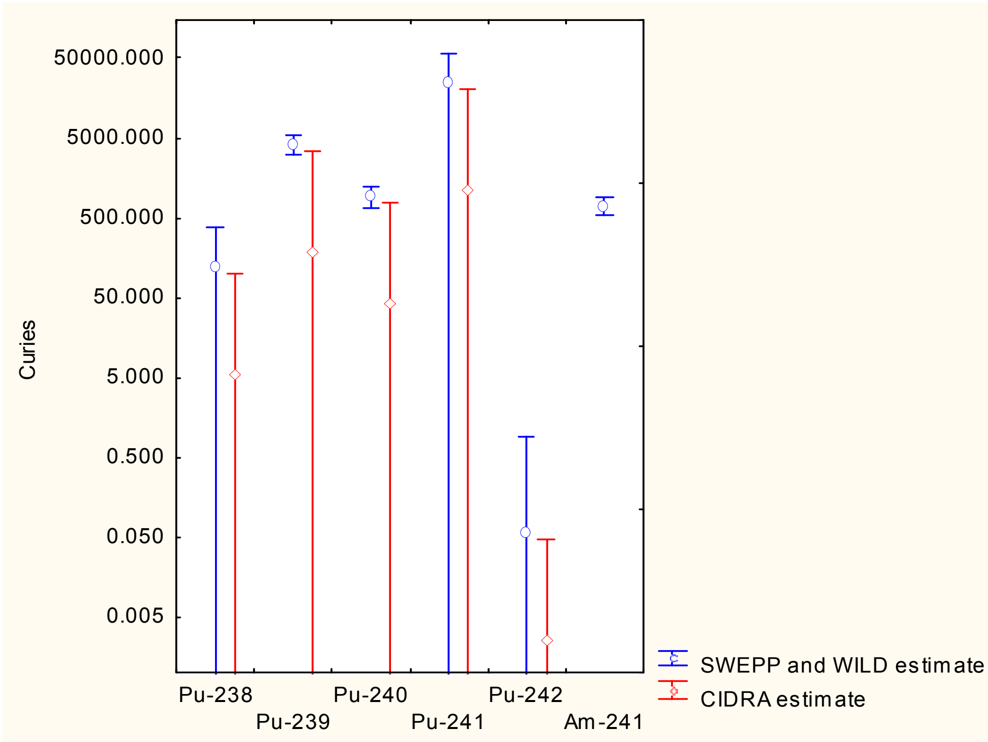

Figure 4-5. SWEPP/WILD vs. CIDRA estimates of SDA RFP buried waste isotopic inventory for special setups sludge.

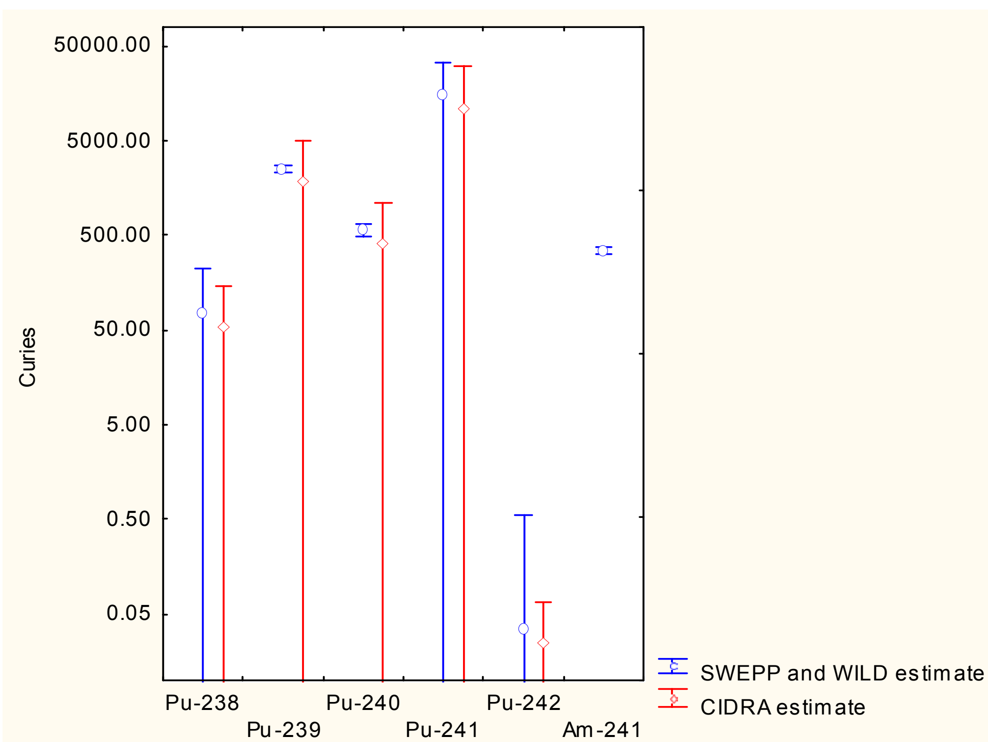

Figure 4-6. SWEPP/WILD vs. CIDRA estimates of SDA RFP buried waste isotopic inventory for graphite.

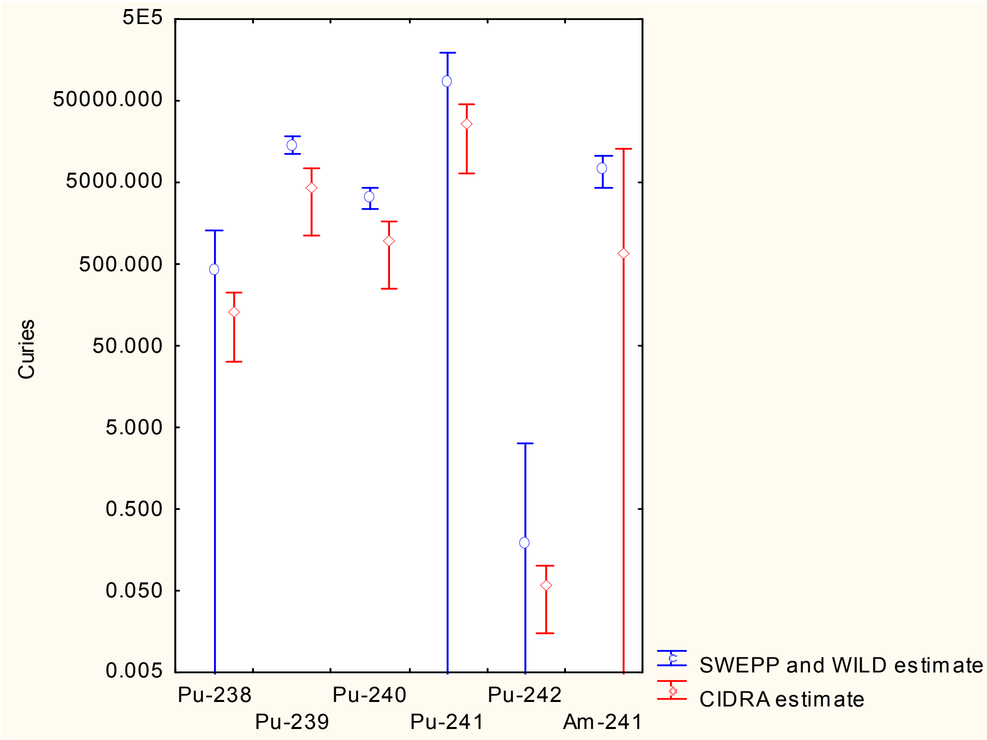

Figure 4-7. SWEPP/WILD vs. CIDRA estimates of SDA RFP buried waste isotopic inventory for filters.

4.4.3 Uranium Content.

As mentioned above, the uranium Curie content in the waste does not contribute to the overall Curie content of the waste when reported to three significant figures. In fact, the Curie content for uranium isotopes amounts to less than 0.01% of the total Curie content shown in Table 4-13. However, the uranium content may still be of interest for other reasons than its total contribution to the inventory. The estimated uranium inventory numbers, available only for the SWEPP/WILD data, are plotted in Figures 4-8 and 4-9. As would be expected based on knowledge of the waste streams, appreciable quantities of uranium occur only in the first and second stage sludge waste type.

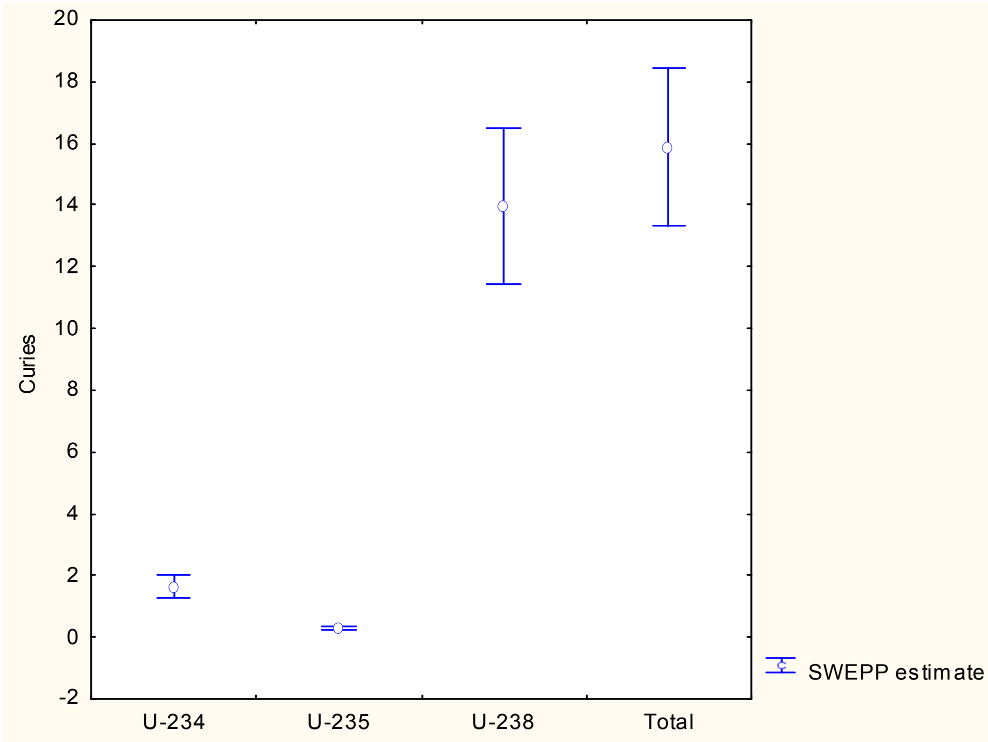

Figure 4-8. SWEPP/WILD estimates of SDA RFP buried waste uranium isotopic inventory.

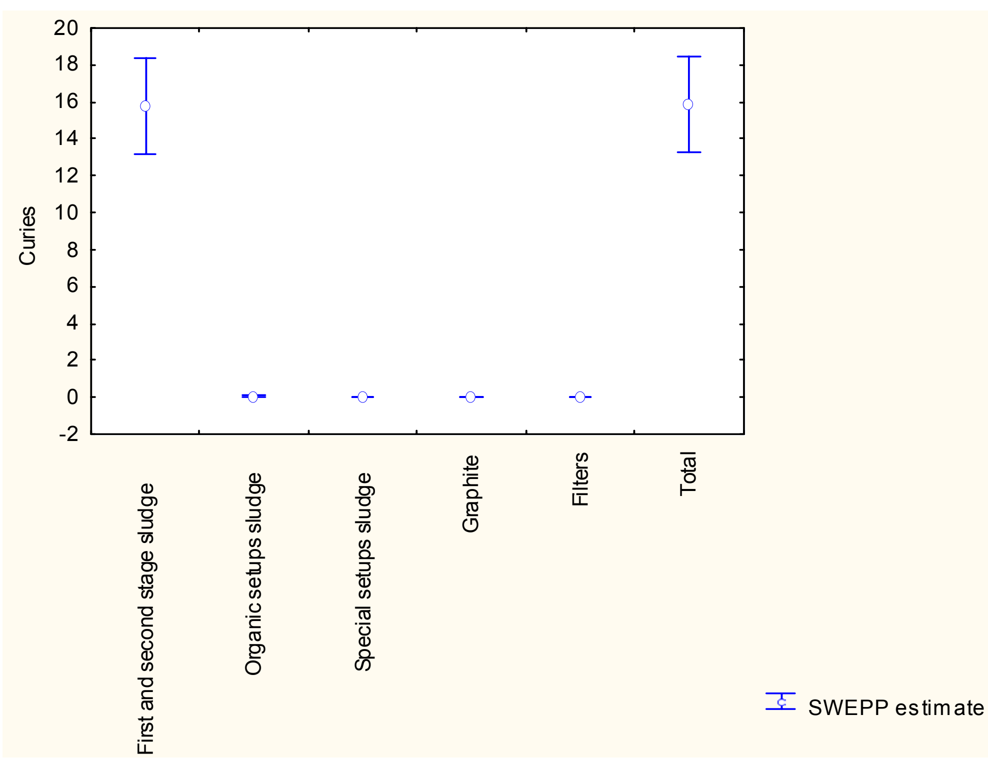

Figure 4-9. SWEPP/WILD estimates of SDA RFP total uranium Curie content by waste type.

4.4.4 Comparability of Americium Data

As discussed previously, to match the CIDRA database numbers, the SWEPP/WILD estimates of Pu isotopic content in the SDA RFP have been given "as generated" mass and Curie content values rather than "as measured" at SWEPP values. This produces notably different inventory numbers primarily for Pu-241 (which has a half-life of 14.4 years), and to a lesser extent, Pu-238 (with a half-life of 87.7 years), because of the length of time between generation and measurement at SWEPP.

The as generated Pu isotopic values were achievable because the known Pu isotopic ratios for as generated weapons grade Pu could be applied to the SWEPP measured Pu-239 quantities. (Pu-239 values as generated and as measured at SWEPP should not be affected by decay because the Pu-239 half-life is 24,000 years.) This avoided having to estimate the waste age at the time of measurement at SWEPP.

In contrast to the plutonium data, the americium data could not be easily adjusted to obtain as generated values because the waste age is not known precisely, and there are no isotopic ratio relationships that can be taken advantage of, as was the case for plutonium. Hence, the reported values are the as measured values. Because a significant amount of americium is generated from the decay of Pu-241 over its short half-life of 14.4 years, some of the observed difference between the SWEPP/WILD and CIDRA estimates of Am-241 can be attributed to the Pu-241 decay. To determine a rough estimate of the degree to which Pu-241 decay is responsible for the greater quantity of Am-241 in the SWEPP/WILD estimates, compared to the CIDRA estimates, a calculation assuming an average age at SWEPP measurement of 20 years was performed. The choice of 20 years average age is somewhat arbitrary, but is a number that has been used previously in EDF-1242 as the nominal age of the waste at the time it was assayed at SWEPP.

The SWEPP/WILD estimated total Pu-241 mass for the five waste types in the RFP SDA waste as generated is 1,620 g. Over 20 years, this Pu-241 quantity would produce 1,004 g or 3483 Ci of Am-241 due to decay. This Curie content is 3.4% of the SWEPP/WILD as measured Am-241 content of 1.02E+05 Ci. Thus, it appears the added Am-241, due to decay, only accounts for a small part of the difference between the reported SWEPP/WILD and CIDRA estimates (since the SWEPP/WILD Am-241 Curie content is 54% greater than the CIDRA estimate).

4.4.5 Excess Neptunium

Another question of interest for this study was whether or not the SWEPP data indicated there might be Np-237 in the waste in excess of what would be generated over time through the decay of Am-241. Data on Np-237 for waste drums measured at SWEPP are available only for drums assayed with the SGRS Absolute system. This included drums in the graphite, filters, and first and second stage sludge waste types. Because there were only four such drums in the graphite category, they were not considered further. There were 281 first and second stage sludge and 54 filters drums with Np-237 data. Data on Np-237 and Am-241 for these drums as given in Table 4-17 were compared to address the question of excess Np-237. (For ease of calculation, the analysis was done in mass units rather than activities.)

Table 4-16. Mean Np-237 and Am-241 mass for first and second stage sludge and filters waste.

Waste type	n	Mean Np-237g	Mean Am-241g	Np-237 as a percentage of Am-241
First and second stage sludge (741-742 IV)	281	.0586	1.946	3.0
Filters (771-776 III)	54	.00507	.155	3.3

The data in the table show that the mean Np-237 mass is 3.0% of the Am-241 mean for first and second stage sludge and 3.3% for filters. By comparison, if the only Np-237 in the waste were due to decay of Am-241, then after 15 years, the measured Np-237 would be 2.4% of the measured Am-241. After 20 years, the relative quantity would be 3.2%. After 25 years it would be 4.0%. Hence, the Np-237 quantity in the first and second stage sludge and filters waste is consistent with Am-241 decayed for approximately 20 years. Thus, there is no indication that there is excess Np-237 in the waste.

5. DISCUSSION

Most of the comparisons between the SWEPP/WILD inventory estimates and the CIDRA radionuclide content estimates of the SDA buried waste for the five waste codes indicate differences that are not statistically significant (as indicated by overlapping error bounds in Figure 4-1 and Figure 4-2. However, it is clear that there is a pattern of the SWEPP/WILD estimates being larger than the CIDRA estimates no matter how the data are broken down (i.e., by waste type or radionuclide). Furthermore, the difference in estimates for Pu-239 (from which the other plutonium isotope values are derived), Pu-240, and for Am-241 are statistically significant. The lack of significance for the differences for the other plutonium isotopes is primarily due to the uncertainty in the isotopic ratios that were applied to the Pu-239 data to obtain the results.

Thus, a general conclusion is that the SWEPP/WILD data calculations indicate a buried waste radionuclide inventory that is significantly greater than that obtained from the CIDRA data, as indicated by the non-overlapping error bounds for the Curie content of the key radionuclides Pu-239 and Am-241. Furthermore, these significant difference would carry over to the comparisons of the other plutonium isotopes and the total Curie content as well, were it not for the uncertainties in the assumed isotopic ratios. The SWEPP/WILD plutonium isotope inventory values were 2.4 times that from the CIDRA database. The SWEPP/WILD Am-241 value was 1.5 times that from CIDRA. The total SWEPP/WILD Curie content estimate for the five waste types considered was 2.0 times the CIDRA estimate.

6. REFERENCES

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